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A STUDY OF THE OCCURRENCE AND MANNER OF DISTRIBUTION OF THE CTENOPHORA OF THE SAN DIEGO REGION

BY
CALVIN O. ESTERLY

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CALVIN O. ESTERLY

(Contribution from the Scripps Institution for Biological Research)

The basis of this paper is found in the results obtained from an enumeration of the ctenophores in 274 surface hauls, and in 816 subsurface collections with closing nets made at the Scripps Institution for Biological Research. They were made between June 16, 1908, and April 17, 1913. The complete data for all hauls is to be published in book form by the Institution and I have given here only the numbers for the successful hauls and the numbers of animals obtained in them. It is to be understood that any other collections made within the periods named above were unsuccessful so far as the Ctenophora are concerned.

The general terms and explanations used in Michael's paper (1911) and in mine (Esterly, 1912) are applicable here. In addition it should be stated that, beginning with haul 2289, all surface collecting has been done with a net of smaller filtering capacity than the 000 silk net. As can be seen from table 1, some of the hauls with the former net (spoken of as the 000 C) obtained *Pleurobrachia* in exceptionally large numbers and the collections would have been larger if the 000 silk net had been used under the same conditions.

Ctenophores were present in 79 of the surface hauls, and 70 of the successful hauls contained specimens of *Pleurobrachia bachei;* that is, 25 per cent of all hauls contained this ctenophore. *Euplokamis californiensis* (probably *Hormiphora palmata*: Bigelow, 1912, p. 381) appeared in fifteen hauls, and *Beroe forskali* in five. It is interesting

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to note that the commonest ctenophore is found much less frequently than the commonest chaetognath or copepod. For example, *Sagitta bipunctata* was obtained in 72 per cent of the surface hauls (Michael, 1911, p. 115), and *Calanus finmarchicus* was present in 57 per cent of the hauls (Esterly, 1912, p. 281). If we consider that the surface hauls are now distributed over parts of five different years, it is not unreasonable to feel that the haul frequency for the Ctenophora would not be changed materially if there were many more hauls available. The difficulty as to irregularity in hauling is the same as that encountered in the studies of chaetognaths and copepods; but certain general conclusions as to the behavior of those groups are justified, and this is apparently true for *Pleurobrachia* among the Ctenophora.

Table 1, which follows, lists the successful surface hauls and the numbers of animals.

TABLE 1

A List of the Successful Surface Hauls, and the Numbers of Animals

	Numbers of Specimens		
Haul No.	Pleurobrachia	Euplokamis	Beroe
1452	1	....	....
1499	253	....	....
1500	181	....	....
1568	20	....	....
1582	.....	1	....
1650	25	....	....
1653	150	....	....
1655	200	....	....
1657	72	1	....
1680	16	1	59
1682	8	1	3
1695	1	1	....
1698	1	1	....
1763	13	....	....
1784	.....	13	....
1804	1	....	....
1836	1	....	....
1850	3	3	....
1854	5	....	....
1875	.....	31	2
1881	.....	16	....
1910	.....	....	....
1915	250	....	....
1920	1	....	....
2178	1	....	....

TABLE 1—(*Continued*)

Haul No.	Numbers of Specimens		
	Pleurobrachia	Euplokamis	Beroe
2179	2	....	....
2182	64	....	....
2207	6	....	....
2213	10	....	....
2224	10	....	....
2228	13	....	....
2255	61	....	....
2259	20	....	....
2264	7	....	....
2271	1	....	....
2331	.....	1	....
2343	.....	1	....
2427	.....	1	....
2571	1	....	....
2639	2	....	....
2645	6	....	....
2662	47	....	....
2680	72	....	....
2692	3300	1	2
2703	101	....	....
2714	330	....	....
2725	144	....	....
2736	750	....	....
2747	1000	....	....
2749	127	....	....
2751	16	....	....
2756	134	....	....
2760	270	....	....
2930	16	....	....
2934	20	....	....
2945	6	....	....
2949	39	....	....
2960	30	....	....
2964	3	....	....
2975	70	....	....
2987	6	....	....
3015	1	....	....
3051	1	....	....
3064	1	....	....
3101	27	....	....
3124	10	2	....
3266	11	....	....
3278	7	....	....
3280	4	....	....
3598	11	....	....
3600	4	....	....
3604	3	....	....
3606	115	....	....

TABLE 1—(*Continued*)

Haul No.	Numbers of Specimens		
	Pleurobrachia	Euplokamis	Beroe
3608	60	....	....
3610	25	....	....
3612	70	....	....
3622	35	....	....
3630	40	....	....
3637	130	....	....

Table 2, which follows, gives the successful hauls with the closing nets, and the number of animals.

TABLE 2

A List of the Successful Hauls With Closing Nets, and the Numbers of Animals

Haul No.	Numbers of Specimens		
	Pleurobrachia	Euplokamis	Beroe
1789	.....	....	9
1821	1	....	....
1827	2	....	....
1852	4	....	....
2335	.....	1	....
2364	.....	1	....
2436	.....	1	....
2449	1	....	....
2468	1	....	....
2482	.....	1	....
2598	1	....	....
2603	1	....	....
2701	1	....	....
2713	2	....	....
2728	1	....	....
2730	5	....	....
2734	2	....	....
2745	1	....	....
2746	15	....	....
3003	1	....	....
3203	2	....	....
3277	14	....	....
3279	4	....	....
3281	2	....	....
3633	5	....	....
3634	10	....	....
3635	1	....	....
3636	15	....	....
3640	1	...	....

The distribution of surface hauls by months is shown in table 3, together with the numbers of hauls that contained *Pleurobrachia* and the number of animals in each month.

TABLE 3

DISTRIBUTION OF SURFACE HAULS BY MONTHS, NUMBER OF HAULS CONTAINING *Pleurobrachia*, TOTAL NUMBER OF ANIMALS OBTAINED

Month	Total Hauls	Successful Hauls	Number of Pleurobrachia
February	16	5	143
March	30	4	23
April	13	6	360
June	83	13	813
July	40	5	30
August	43	25	6500
September	6	2	251
October	20	0	0
November	6	4	81
December	17	8	139

Table 3 shows that there is a marked seasonal variation in abundance, many more animals being obtained in August than in any other month. The question at once arises: What makes August the most favorable season of the year? The hydrographic conditions, such as temperature or salinity, may be at the optimum then; if so, that fact should appear in the data on record. On the other hand, the time when the organisms appear in greater numbers is undoubtedly related to the time of reproduction and to the growth periods, so that, generally speaking, the animals will, under most circumstances, appear in maximum numbers at a given time after the production of eggs. It is, however, not unreasonable to assume that certain environmental conditions are more favorable from the very fact that the organisms are found in overwhelmingly greater numbers at a certain time of the year.

So far as I have been able to discover, there is nothing in the literature that deals with periods of reproduction and growth in any of the Ctenophora. And up to the present I have failed to find anything in our collections or field data that will show when eggs are produced or how long it is until the animals reach the adult stage. It seems necessary, then, on account of lack of knowledge with regard to breeding habits, to consider the relation between abundance and conditions that are taken account of in our present methods of investigation.

There is a rather sharp separation of the months named in table 3 into two groups according to the prevailing surface temperatures. This is shown to some extent in table 4, which follows.

TABLE 4

Number of Surface Hauls by Months and According to Different Temperatures

Temperature	June	July	August	Sept.	Oct.	Nov.	Dec.	Feb.	March	April
14° and less	0	0	0	0	0	0	0	8	0	3
14°.1–15°	0	0	0	0	0	0	5	8	22	5
15°.1–16°	0	0	0	0	0	1	3	0	4	2
16°.1–17°	27	3	0	1	0	1	9	0	1	3
17°.1–18°	27	1	0	0	0	2	0	0	0	0
18°.1–19°	11	9	0	3	2	1	0	0	0	0
19°.1–20°	2	12	14	1	12	0	0	0	0	0
20°.1 and more	0	11	24	1	2	0	0	0	0	0

It will be seen from table 4 that during June, July, August, September and October the temperature of the surface water was always above 16° C, while during the other months the temperatures were 15° C or less. Since there is such a difference in temperatures the first five months in table 4 (spoken of hereafter as "summer months," for convenience) are regarded as a group to be set off against the others, which are called the "winter months." It should be explained that the temperatures were not taken for all the surface hauls, so that there are fewer entered in table 4 than in table 3. August is the warmest month, on the whole, for all hauls were made in water above 19°, and Feburary is the coldest, since the temperatures at the time of hauling were all at 15° or less. It may be well to state here that very recently (August, 1913), it has been found that in the vicinity of Santa Monica the water is considerably colder in August than about San Diego, and that *Pleurobrachia* occurs in large numbers in the cold water. These hauls, however, do not enter into the tables discussed here, for the hydrographic conditions in the more northern locality seem to be so different that the collections made there will be considered by themselves.

One noticeable thing about the specimens of *Pleurobrachia* obtained in warm surface water, as compared with those taken in colder water, is that all of the former are of small size, while among the latter

large individuals are not uncommon. For example, of the hauls in table 1 numbers 2639 to 2762 were made in August, 1912. Out of a random sample of 100 animals from haul 2747, only two were between five and seven millimeters in height, while the rest were from one to four millimeters high; there were two animals in the haul that measured nine millimeters in height. Haul 2692 did not contain any of the larger animals, the majority of the specimens being between four and seven millimeters. The other August hauls are very similar to 2747 and 2692.

In hauls 3598–3637, on the other hand, which were made in February and April, 1913, the number of large animals was much greater. For example, haul 3637 (April) contained fifteen animals between twelve and fifteen millimeters high, but most of the specimens were small, averaging from three to six millimeters. In haul 3606 (February) most of the animals were from ten to twelve millimeters, while the smallest ones were not under seven. The three animals in 3604 (February) were ten, twelve and fourteen millimeters high. While it is true that large hauls like 3606, 3608, and 3612 contain animals from five to seven millimeters in height, the August hauls in the warm region do not contain any that reach ten or twelve millimeters. The nine hauls made in August in the colder water mentioned do, however, contain the large animals in about the same proportion as the February and April hauls. Of the six successful hauls in the former group, only one was made in water above 18°, the other five being between 16° and 18°. While the temperature of these hauls is higher than that for most of the February and April hauls, it is true, nevertheless, that the larger specimens of *Pleurobrachia* are found only in water under 18°, as far as our investigations have gone. The collections in February, March and April in the south and those in the north (August only) alone contain Pleurobrachias that reach a size of ten or twelve millimeters. I am unable to say what significance this may have. There may be some meaning in the fact that the large animals did not appear in our collections made in November and December when the colder temperatures prevail. Likewise, it may be significant that no large animals have been taken in June and July, although there are more than fifty hauls made in water of temperatures at which they appeared in August around Santa Monica. A discussion of the questions involved in the appearance of the large and presumably adult specimens of *Pleurobrachia* at certain seasons and under particular conditions would be subject to so much speculation

at this time that it will not be entered into. What follows deals with the relation between abundance and external factors without regard to the stage of growth of the animals.

The *Pleurobrachia* of this coast is probably a variety of *P. pileus* of the Atlantic. Bigelow (1912, p. 374) states that in his opinion *bachei* is not the same as *pileus*, but Mayer (1912, p. 13) says *pileus* is "commonly called *bachei* on the Pacific Coast." The Atlantic form seems to be found mostly in cold water. Mayer states that it is found off southern New England early in April and disappears as the water grows warmer so that it does not occur there during the summer. It is found, however, in vast swarms during the summer in the cold water of Maine and Nova Scotia. Dr. Bigelow writes in a letter that the surface temperature off Portland, Maine, during July and August ranges from 14° to 15.5° and drops to 10° off Eastport. He has met swarms of *Pleurobrachia* in the summer at 14° and in January at 7° in Massachusetts Bay and has found *P. bachei* at Acapulco at about 27°. According to Steuer (1910, pp. 571, 572), *Pleurobrachia pileus* was most abundant in the Adriatic from January through April from 1900 to 1904. From 1898 to 1904 this ctenophore was of irregular occurrence during June, July, August, September and October, and was not taken at all during August. Such general observations as have been set down indicate that *Pleurobrachia* is typical of cold water, and Steuer states (p. 485) that *pileus* is one of three characteristic ctenophores of the polar region. It seems certain that the temperatures at which *Pleurobrachia* is particularly abundant here and in the Atlantic are markedly different, but a detailed comparison is hardly possible at this time.

TABLE 5

Total Number of Hauls, Number of Successful Hauls, Numbers of *Pleurobrachia*, in Hauls During Each of the Summer Months at Temperatures Above 16°. Left-Hand Figures, Total Hauls; Center Figures, Successful Hauls; Right-Hand Figures, Numbers of Animals.

Temperatures	June			July			August			September			October		
16°.1–17°	27	2	9	3	0	0	0	0	0	1	0	0	0	0	0
17°.1–18°	27	2	2	1	0	11	0	0	0	0	0	0	0	0	0
18°.1–19°	11	3	110	9	2	11	0	0	0	3	1	250	2	0	0
19°.1–20°	2	1	253	12	1	1	14	10	3868	1	1	1	12	0	0
20°.1 and more	0	0	0	11	2	21	24	12	2556	1	0	0	2	0	0

Table 5 considers the distribution of *Pleurobrachia* for the summer months with regard to temperature, giving the total number of hauls, the number of successful hauls and the total number of animals. Temperatures below 16.1° are not included because, as may be seen in table 4, no hauls were made at those points in the months considered.

The number of animals obtained in August is many times greater than in any other month, and temperatures above 19°.1 are characteristic and more favorable for the species than in any other month. It seems plain, however, that temperature is not to be considered alone, for during July there were almost as many hauls at high temperatures as during August; yet the animals were rare. During October also, more collecting was done than in August at temperatures that would seem to be most favorable (judging by numbers of specimens obtained) during the latter month, but all the October hauls were unsuccessful. Some other factor, which does not appear in our data, is surely concerned, for otherwise the numbers of animals taken in July and October should at least approach those in August. If the prevailing temperature makes the season, July and October ought to be as favorable as August.

The other factor undoubtedly stands in some relation to the appearance of the large animals as already set forth, but I cannot say more than this at present.

In table 6, which follows, there is a summary of the relation between abundance of *Pleurobrachia* and temperatures when all the summer hauls are combined. The prevalence of the animals at high temperatures is strikingly shown, though it should not be forgotten that the August collections furnish most of the animals and a large proportion of the successful hauls.

TABLE 6

DISTRIBUTION OF *Pleurobrachia* AT THE SURFACE WITH REGARD TO TEMPERATURE: SUMMER MONTHS

	Temperature	No. of hauls: Total.	No. of hauls: Success.	No. of hours: Total.	No. of hours: Success.	No. of animals: Total.	No. of animals: Per hour.	Frequency: Haul.	Frequency: Time.
1.	17° and less	30	2	23.6	0.8	9	0.4	7	3
2.	17°.1–18°	28	2	24.8	1.3	2	0.08	7	5
3.	18°.1–19°	25	6	19.4	4.5	371	24.1	24	22
4.	19°.1–20°	31	13	33.4	9.6	4119	130.4	37	25
5.	20°.1 and more	38	14	24.7	10.4	2577	115.	31	38

It is plain from this table that the average number of animals obtained per hour is highest when the temperature ranges from 19° to 20° (line 4), and that the next highest hourly average is at temperatures of 20°.1 or more (line 5). The numbers of animals obtained at temperatures of 18° or less are practically negligible, and the frequencies are very low, while between 18°.1 and 19° the hourly average and the frequencies show a marked advance toward the maxima. That is, the abundance is greatly increased after the temperature rises above 18°, and becomes overwhelmingly greater above 19°.

Tables 5 and 6 emphasize the manner of distribution of the Pacific form of *Pleurobrachia*, both as to season and temperature. Whether the organisms referred to by the names *pileus* and *bachei* are actually of the same kinds or not, they are certainly much alike in structure. Their unlike behavior, however, may be an index to quite dissimilar constitutions not revealed by the visible makeup. In the Atlantic the ctenophore is more abundant when the temperatures are lower; in the Pacific the reverse appears to be the case. But since season and temperatures are associated in characteristic ways, it is hard to distinguish between their effects. As already mentioned, temperature does not alone bring abundance of ctenophores, because we have records of numbers of hauls, at as high temperatures as those of August, in which the animals were of very infrequent occurrence.

Pleurobrachia occurs in this region in relatively small numbers during the winter when the water is much colder than in the summer, but, as has been stated, the proportion of large animals is much greater in the winter; in fact, it is not known that specimens over 9 mm. in height are found in water above 17°. If such temperatures are found during the summer the large animals are obtained, as already stated in the account of the collections made in the vicinity of Santa Monica. Table 7, dealing with winter months, is similar to table 5 for the summer months.

TABLE 7

Total Number of Hauls, Number of Successful Hauls, Numbers of *Pleurobrachia*, in Hauls During Each of the Winter Months at Temperatures Up to 19°. Left-Hand Figures, Total Hauls; Center Figures, Successful Hauls; Right-Hand Figures, Numbers of Animals.

Temperatures	Nov.			Dec.			Feb.			March			April		
14° and less	0	0	0	0	0	0	8	4	28	0	0	0	0	0	0
14°.1–15°	0	0	0	5	2	28	8	1	115	22	4	23	0	0	0
15°.1–16°	2	2	26	2	1	8	0	0	0	1	0	0	1	0	0
16°.1–17°	6	6	164	3	1	1	0	0	0	1	0	0	3	0	0
17°.1–18°	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18°.1–19°	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Out of the sixty-nine hauls considered in table 7, twenty-one were successful, all made in water below 17°. The frequency is 30, while during the summer (table 5) it is about 20. In other words, *Pleurobrachia* is found more often in this region when the water is below 17° than when it is above that point, but the abundance is far greater during the summer in warmer water. There is little more than this to be said about the winter collecting as compared with that during the summer, for the number of winter hauls is rather small.

A consideration of the effect of salinity on abundance is based on 126 hauls of which 23 were successful. The August collections contained most of the animals. Table 8 deals with the summer hauls for which the salinities have been determined.

TABLE 8

Total Number of Surface Hauls, Number of Successful Hauls, Number of *Pleurobrachia*, in Hauls During Each of the Summer Months at Different Salinities. Left-Hand Figures, Total Hauls; Center Figures, Successful Hauls; Right-Hand Figures, Number of Animals.

Salinity	June			July			August			September			October		
33.60 or less	20	4	26	11	1	8	1	1	127	0	0	0	1	0	0
33.61–.65	15	1	150	11	2	21	4	3	744	0	0	0	2	0	0
33.66–.70	15	2	73	4	1	3	3	2	173	1	1	250	1	0	0
33.71–.75	8	1	13	4	1	1	3	2	1750	0	0	0	5	0	0
33.76–.80	4	0	0	2	0	0	2	1	134	1	0	0	0	0	0
33.81–.85	3	0	0	1	0	0	1	0	0	1	0	0	2	0	0

During August the most favorable salinity is within the limits 33.71 and 33.75, but there is also the seasonal effect to reckon with as was the case in the consideration of the effect of temperature. It will be noted that more hauls were made in June, July and October than in August at salinities between 33.71 and 33.75, but during the three former months only 14 animals altogether were obtained. This seems to indicate that the external conditions which favor great abundance of *Pleurobrachia* are not alone those of certain salinities any more than those of certain temperatures. The season has its effect; but it is not plain why August is so much more favorable than June, for example, in table 8 or October in table 5.

Table 9 is an arrangement of results with regard to salinity that combines all the summer hauls. While the seasonal effect of August collecting necessarily enters, this table shows, nevertheless, what may

be regarded as the optimum salinity on the whole. The "best season" does not consist alone of a particular and favorable salinity, if it may be assumed that abundance is an index of the favorable or unfavorable character of the surroundings. For example, in table 8 we assume that August is the favorable season and 33.71–33.75 the favorable salinities because the abundance of *Pleurobrachia* is so much greater in that month and at those salinities. Yet that range of salinity is not characteristic of August any more than of October judging from the total number of hauls. So, while we should keep in mind that there is a combination of the effects of season and salinity in table 9, there is meaning in the general results with regard to salinity shown in the table.

TABLE 9

Distribution of *Pleurobrachia* at the Surface According to Salinity, Summer Months

	Salinity	No. of hauls: Total. A	No. of hauls: Success. B	No. of hours: Total. C	No. of hours: Success. D	No. of animals: Total. E	No. of animals: Per hour. F	Frequency: Haul. G	Frequency: Time. H
1.	33.60 or less	33	6	25.4	5.1	161	6.4	18	20
2.	33.61–.65	32	6	25.2	4.3	915	36.	19	17
3.	33.66–.70	24	6	17.7	3.3	499	28.2	25	19
4.	33.71–.75	20	4	18.9	3.4	1764	94.3	20	18
5.	33.76–.80	9	1	9.5	.8	134	14.	11	8
6.	33.81–.85	8	0	8.9	0.	0	0.	0	0

The largest number of animals per hour is found in line 4, column F; that is, the organisms are most abundant at salinities between 33.71 and 33.75. Out of 3474 specimens, 3178 were obtained at salinities ranging from 33.61 to 33.75, and of the latter number, more than half were taken in hauls made at salinities from 33.71 to 33.75.

As has been shown in the preceding account of the effects of temperature and salinity, August is the month during which *Pleurobrachia* is particularly abundant. In table 5 it appears that August temperatures are all above 19°.1, so that high temperatures are characteristic. The salinities at which the abundance is greatest range from 33.71 to 33.75, but it cannot be said that they are specially characteristic of the month, as can be seen in table 8. Furthermore, we find that the numbers of animals taken during the others of the summer months do not nearly approach those obtained during August, though as many or more hauls were made at the same temperatures and salinities that were so favorable when collecting was done in August.

There is nothing apparent in our data to show why August should be the best season, but, regardless of that, it can be seen that temperatures above 18° (table 6) and salinities ranging from 33.61 to 33.75 (table 9) are most favorable. The interaction of the effects of temperature and salinity is shown in a general way in table 10, in which are considered the hauls made at favorable (33.61–33.75) and unfavorable (33.60 or less, and 33.76–33.85) salinities and at the temperature groups as shown.

TABLE 10

DISTRIBUTION OF *Pleurobrachia* AT THE SURFACE, AT OR BELOW, AND ABOVE 18°; SUMMER MONTHS

Temperature	No. of hauls: Total.	Success.	No. of hours: Total.	Success.	No. of animals: Total.	Per hour.	Frequency: Haul.	Time
	A	B	C	D	E	F	G	H
I. SALINITIES RANGING FROM 33.61 TO 33.75								
At 18° or below	31	1	26.2	0.25	1	0.04	3	1
Above 18°	38	15	32.5	9.7	3177	97.7	40	30
II. SALINITY 33.60 OR LESS, AND FROM 33.76 TO 33.85								
At 18° or below	24	4	19.5	2.5	26	1.3	17	13
Above 18°	24	3	19.4	3.5	269	14.	12	18

The table is practically self-explanatory, and shows that, no matter what groups of salinities are considered, the collecting was about equally divided between favorable and unfavorable temperatures. This eliminates the possibility that successful collecting at the favorable salinities is due to the prevalence of favorable temperatures. There is a range of favorable salinities but more animals are obtained above 18° than below, regardless of the salinity. The cause of the rarity of specimens in part II of table 10 cannot be prevalence of supposedly unfavorable temperatures.

Winter hauls for which salinities are known are so few that their consideration is omitted.

It might be expected that the ctenophores execute diurnal movements as do the chaetognaths and copepods, but an examination of our data does not lead to very certain results in that regard. Table 11 brings together the surface hauls as arranged to show the abundance through the day by two-hour periods.

TABLE 11

Distribution of *Pleurobrachia* at the Surface, by Two-Hour Periods Throughout the Day, Summer Months

	Time of Day	No. of hauls: Total. A	No. of hauls: Success. B	No. of hours: Total. C	No. of hours: Success. D	No. of animals: Total. E	No. of animals: Per hour. F	Frequency: Haul. G	Frequency: Time. H
	A.M.								
1.	6– 8	31	8	20.4	7.2	754	37.	27	35
2.	8–10	24	3	22.1	2.5	430	17.	12	11
3.	10–12	19	3	12.4	1.5	72	5.8	16	12
	P.M.								
4.	12– 2	16	0	13.3	0.	0	0.	0	0
5.	2– 4	10	4	6.2	1.5	524	84.5	40	24
6.	4– 6	10	3	6.2	1.8	36	5.5	30	27
7.	6– 8	27	9	15.2	4.2	544	35.4	35	28
8.	8–10	7	3	3.9	1.4	15	3.1	43	36
9.	10–12	1	0	2.8	0.	0	0.	0	0
	A.M.								
10.	12– 2	2	0	2.	0.	0	0.	0	0
11.	2– 4	10	2	8.	1.8	75	9.4	20	22
12.	4– 6	35	8	26.	6.8	5065	195.	23	26

The average number of animals per hour (column F) is greatest between 4 and 6 A.M. (line 12) and the highest frequencies are found in line 8. While the table as a whole does not show clearly that diurnal migrations occur, it at least makes clear that during the summer the optimum conditions are found at sunrise or shortly after. The large number of animals taken from 4–6 A.M. is due almost entirely to August hauling, since all but 15 of the 5065 specimens were obtained during that month. Of the total number recorded for 6–8 A.M. all but 14 were in August hauls. The somewhat irregular results in the table do not allow more than the statement that the time of the surface plurimum for August is from 4–6 A.M., but it is not unlikely that this is true for the entire summer. According to Mayer (1912, p. 12) the ctenophores are very sensitive to rough water, and it might be that the early morning plurimum found here is due to the quietness of the sea at that time. It hardly seems probable that this is the explanation but the possibility should not be disregarded.

It is worth noting that in table 11 there are no successful hauls from 12 to 2 P.M., and some of these are August hauls. Another time of unsuccessful collecting is from 10 A.M. to 2 P.M., but this may not have much significance on account of the small number of hauls. The implication in such results is that the animals leave the surface at the times when surface hauls are unsuccessful and return to the surface later.

It can only be said that if vertical migrations take place, there is no evidence to that effect in our data. *Pleurobrachia* was obtained with the closing nets in 29 hauls. It was not taken below 50 fathoms: each of four hauls from 50 to 40 fathoms with the Nansen net contained one animal; five were taken in one haul at 30–25 fathoms, two in two hauls at 20–15, four in three hauls at 10–5, and 22 in three hauls between five fathoms and the surface. The Kofoid net obtained *Pleurobrachia* in ten hauls between 4 and 15 fathoms, there being 38 specimens in all, 15 of them in one haul at nine fathoms. It seems surprising that there were not more successful hauls in such a large number with the closing nets. As it is, there is nothing to show where the animals are during the time when they are absent from the surface.

These results are interesting in view of certain statements of Mayer (1912). He says (p. 12) that the ctenophores sink far into the depths during storms, and that the surface must have been very smooth for hours before the organisms move upwards from their "deep retreat." Such observations may show why *Pleurobrachia* is taken in such a small proportion of surface hauls, but they increase the expectation that closing hauls ought to be more successful than in our experience.

We are in position to speak on the basis of a few hauls only with regard to the manner of occurrence of the other ctenophores, so that it is uncertain what their behavior really is. Some points, however, are of interest.

Euplokamis (*Hormiphora*) was obtained in 17 hauls, 15 of which were made in the summer. During July, 63 animals were taken in four hauls; during June there were nine in nine hauls, and one in both August and September. July, therefore, is as pre-eminently a favorable season for *Euplokamis* as August is, in comparison, for *Pleurobrachia*. Furthermore, considering the summer season as a whole, all the hauls from 10 p.m. to 2 a.m. (3 in number) were successful and contained 49 of the 74 animals. Specimens did not appear in any of the hauls between 8 a.m. and 6 p.m. The time of the plurimum of *Euplokamis* at the surface is during the period when *Pleurobrachia* is rare or absent, so there is a suggestion that the two organisms are distinguished by their behavior as well as by their structure. This point has been developed at greater length in connection with studies from the Institution on the Chaetognatha (Michael, 1911) and the Copepoda (Esterly, 1912). Its apparent recurrence here is, consequently, worth noting.

We obtained 73 specimens of *Euplokamis* in 13 hauls for which temperatures were taken and 65 of them appeared when the temperature ranged from 18°.1 to 19°. The frequencies are so much higher then, also, that it hardly seems that the results are due to coincidence.

The results with regard to salinity are decisive as far as they go, but since there are only seven successful hauls the mere mention of the results is sufficient. Thirty-five animals were obtained, of which 32 were taken in water ranging from 33.61 to 33.65 in salinity, two at 33.60 or less and one between 33.60 and 33.70.

Four specimens of *Euplokamis* were obtained in four hauls with the Nansen nets, and all between 30 and 75 fathoms. There was one specimen in a haul with the Kofoid net at 150 fathoms.

Beroe is represented by sixty-six specimens taken in four hauls. Sixty-two of these animals were present in two June hauls made between 6 and 8 P.M. The temperature during one of the hauls, which obtained three animals, was 16°.3; the temperature of the other haul is unrecorded, but there is reason to think it was about 16°. Here also is the indication of specific behavior when these results are compared with those relating to the other ctenophores. *Beroe* was obtained in one haul with the Nansen net, there being nine specimens from a depth of 12 fathoms; the net was hauled horizontally.

SUMMARY

If the behavior of the ctenophore *Pleurobrachia bachei* is compared with that of the chaetognath *Sagitta bipunctata* (Michael, 1911) or of the copepod *Calanus finmarchicus* (Esterly, 1912), the most striking difference is in the exceeding rarity of the ctenophore in sub-surface hauls. The chaetognath named and the copepods in general appear to have well-defined levels below the surface (centers of migration) at which they are more abundant than at the surface, at certain times, and from which they move to or toward the surface at regular intervals during the twenty-four hours. There is no evidence at hand that the ctenophores perform these depth migrations, though they are absent from the surface at certain times of the day. It is impossible to say what becomes of the animals during the time they are absent from the surface. It is hardly probable that their absence from the surface at specified times is due to coincidence.

Since we have found that certain temperatures and salinities are supposedly favorable, it might be suspected that periodicity of appearance at the surface is in some way connected with these factors, but our field data are inadequate for determining this point. It is known, however, that the temperatures and salinities at which larger catches are made do not prevail during the *periods* of greatest abundance.

Pleurobrachia is more abundant by far in August than in any other month, and it is mainly due to the results of August collecting that large numbers of animals are set down under certain temperatures and salinities almost to the exclusion of others. With this in mind, it may be stated that during the "summer" (June to October) *Pleurobrachia* is more abundant above 18° than below; it is especially abundant above 19°, but temperatures above 20° are apparently not so favorable as those between 19° and 20°. Furthermore, salinities ranging from 33.61 to 33.75 are optimum during the summer but more animals were taken between 33.71 and 33.75 than at any other points.

As was indicated in the course of the paper it does not appear why August should be the best season. That month, as shown in table 3, is characterized by high temperatures in the vicinity of San Diego, but the same temperatures in other months (October, for example) are not those at which the organisms are most abundant. What other factors enter into this is largely a matter of conjecture at present. We know that the ctenophore is obtained during the winter in fairly large numbers when the water ranges from 14° to 16° in temperature. Some of the animals that are taken under those conditions are characterized by their large size; they may reach a height of 12 or 15 mm., while during the summer all the animals are small, those 9 mm. high being of rare occurrence. The large specimens have been taken during August in the region around Santa Monica, where the temperature of the hauls averaged 16°–17°. The winter collections and those in summer in the colder water both contain animals as small as any taken in warm water, but large animals do not appear except in the collections from cold water. The fact that we get large animals during August if the water is about 16°, as well as during the winter, seems to indicate strongly that the matter of seasonal distribution is connected with the time of the appearance of the large and presumably mature animals.

The principal aim of this paper has been to set forth as far as possible, on the basis of our field data, something about the manner of

distribution and the behavior of the ctenophores of this region. It deals mainly with *Pleurobrachia* since it is the only one that is found often enough to make a detailed study justifiable. Many of the statements made are facts that are derived from our present data. The bearing of some of the things known is not understood, but we have found out something about the biology of the ctenophores. Whatever appears to be of the nature of a conclusion must be regarded as tentative, but it is hoped that the recorded observations will prove suggestive. The present indecision in certain regards does not make it less desirable to bring out what we can.

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BIBLIOGRAPHY

Bigelow, H. B.

1912. Reports of the scientific results of the expedition to the eastern tropical Pacific, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905, Lieut.-Commander L. M. Garrett, U.S.N., commanding. XXVI. The Ctenophores. Bull. Mus. Comp. Zool. Harvard College, **54**, 369–404, pls. 1, 2.

Esterly, C. O.

1912. The occurrence and vertical distribution of the Copepoda of the San Diego Region, with particular reference to nineteen species. Univ. Calif. Publ., Zool., **9**, 253–340, 7 figs. in text.

Mayer, A. G.

1912. The ctenophores of the Atlantic Coast of North America. Publ. Carnegie Inst., **162**, 58 pp., 16 pls., 76 figs. in text.

Michael, Ellis L.

1911. Classification and vertical distribution of the Chaetognatha of the San Diego Region including redescriptions of some doubtful species of the group. Univ. Calif. Publ. Zool., **8**, 21–186, pls. 1–8.

Steuer, A.

1910. Planktonkunde (Leipzig und Berlin, B. G. Teubner). xvi + 723, 1 pl., 365 figs. in text.

Torrey, H. B.

1904. The ctenophores of the San Diego Region. Univ. Calif. Publ., Zool., **2**, 45–51, pl. 1.

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